CRITERION 418

VACUUM PUMPS

SIGNATURES

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RECORD OF REVISIONS

Revision No.	Date	Description
0	01/03/02	Initial Issue. Reviewed DOE operating experiences and ORPS from January 1995 through July 2001.
	9/19/02	Revision incorporating formatting based on Criterion 101 Writers Guide.

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VACUUM PUMPS

1.0 PURPOSE

It is the purpose of this document is to define the minimum requirements for the operation and maintenance for LANL vacuum pumps and their appurtenant equipment.

This document addresses the requirements of LIR 230-05-01, "Operations and Maintenance Manual".

Implementation of this Criterion satisfies DOE Order 430.1A (Ref 10.2) for the subject equipment / system. DOE Order 430.1A (Ref 10.2)"Life Cycle Asset Management," Attachment 2 "Contractor Requirements Document," Paragraph 2, Sections A through C, which in part requires UC to "…maintain physical assets in a condition suitable for their intended purpose," and employ "preventive, predictive, and corrective maintenance to ensure physical asset availability for planned use and/or proper disposition." Compliance with DOE Order 430.1A is required by Appendix G of the UC Contract.

2.0 SCOPE

The scope of this Criterion includes the routine inspection, testing and maintenance of rough and medium vacuum pumps at all nuclear and non-nuclear LANL facilities. The type of vacuum pumps includes rotary vane, reciprocating, rotary piston, liquid-ring, centrifugal and axial flow blowers, rotary screw type, lobed rotor (Roots), and diaphragm pumps throughout the LANL complex. Appendix A delineates the types and catagories of mechanical vacuum pumps that are available for rough and medium vacuum service. Maintenance of the electric drive motors for vacuum pumps, larger than 2 HP, is presented in Criterion 510, "Electric Motors".

This document does not include mechanical pumps used in explosive environments, high vacuum equipment such as cryopumps, turbo-molecular pumps, ion pumps, diffusion pumps or mechanical backing pumps on leak detectors. This Criterion does not address corrective maintenance actions required to repair or replace equipment.

3.0 ACRONYMS AND DEFINITIONS

3.1 Acronyms

AHJ	Authority Having Jurisdiction
CFR	Code of Federal Regulations
CMMS	Computer Maintenance Management System
JCNNM	Johnson Controls of Northern New Mexico

ML	Management Level
ORPS	Occurrence Reporting and Processing System
PMI	Preventive Maintenance Instruction
PP&PE	Personal Property and Programmatic Equipment
PSIA	Pounds per square inch absolute
RP&IE	Real Property and Installed Equipment
SSC	Structures, Systems and Components
UC	University of California

3.2 Definitions

Management Level Determination (ML1, ML2, ML3, ML4)-A classification system for determining the degree of management control applied to facility work. See LIR 230-01-02 for definitions of each ML level.

Torr: (After Torricelli) Standard atmospheric pressure is 760 torr. 1 torr is equal to one (1) mm Hg. (1,000 microns). Atmospheric pressure in Los Alamos is approximately 575 torr. Definition per Vacuum Technology by Edwards High Vacuum, 1981, Page 6 (Reference 10.12).

Vacuum: Any pressure less than atmospheric pressure.

Table 3.1 Vacuum Regimes

Course or rough vacuum	**760 torr-----1 torr**
Medium vacuum	**1 torr----10^{-3} torr**
High vacuum	**10^{-3}torr----10^{-8} torr**
Ultra- high vacuum	**10^{-8} torr and below**

Definition per Vacuum Technology by Edwards High Vacuum, 1981, Page 7 (Reference 10.12).

Atmospheric Pressure: The pressure exerted by the atmospheric air. At sea level, this pressure is 29.92 in.Hg or 14.7 PSIA. At LANL, the atmospheric pressure is 22.65 in. Hg or 11.2 PSIA. Definition per Gast Manufacturing Company, Vacuum and Pressure Systems Handbook, Page 2, 1986 edition (Reference 10.17).

Micron: A metric measure with a value of 10^{-6} meters. In this context a micron unit is used to provide relative pressure in vacuum terminology. In vacuum technology, micron is a common term; however, the meaning is actually micrometer Hg. Standard atmospheric is 760,000 microns. Many mechanical vacuum pumps have blank off

pressures in the range of 1 to 5 microns. Definition per Facility Piping Systems Handbook, page 15.6, 1996 (Reference 10.27).

mm Hg: Millimeters of mercury. In vacuum technology, mm Hg is commonly used to express a measure of vacuum or absolute pressure. Atmospheric pressure is 29.92 in.Hg or 760 mm Hg. absolute. Definition is per author.

in. Hg: Inches of Mercury: In vacuum technology, in. Hg is used to represent absolute pressure readings; that is, vacuum readings which are relative to a perfect vacuum. A perfect vacuum is 0 psia or 0 in. Hg. In. Hg is also referenced to atmospheric pressure. Vacuum gauges can read 10 in. Hg and thereby indicate a vacuum, or pressure, that is 10 in. Hg below atmospheric pressure. Definition is per author.

Ultimate Pressure: Refers to the blank-off pressure of all vacuum pumps, including mechanical vacuum pumps. It is the lowest pressure, or best vacuum, that this design of pump can achieve. Definition per Leybold Ag., Product and Vacuum Technology Reference Book, 1990, Vacuum Technology Section 18; Page 4, (Reference 10.8).

Reciprocating Vacuum Pumps (Positive Displacement):

- **Rotary Piston**: An eccentrically mounted cam causes the piston to rotate and the neck of the piston to oscillate. The eccentrically mounted cam and piston divide each pumping chamber into two crescent shaped chambers for expansion and compression. The size of the expansion and compression chambers change during the work cycle. Definition per Leybold Ag., Product and Vacuum Technology Reference Book,1990, Vacuum Technology section; Page 78 (Reference 10.8).
- **Diaphragm Type**: These are reciprocating pumps that have a driven diaphragm that is moved by a connecting rod. The resulting diaphragm motion produces a differential pressure across the pump. These pumps have a definite advantage in that they do not have any sliding moving parts and do not require lubrication. Definition per Vacuum and Pressure Systems Handbook, 1986 edition by Gast Manufacturing Company (Reference 10.17, PG. 21)

Rotary Motion Pumps (Positive Displacement):

- **Rotary Vane Pumps**: A rotor is mounted eccentrically in the pump cylinder so that there is a crescent shaped pumping chamber between the rotor and the pump cylinder. The pumping chamber is divided by two vanes that fit into a slot in the rotor. The vanes are drawn against the outer wall by centrifugal force as the rotor rotates. A thin film of oil seals the clearance between the vanes and the pump cylinder. Definition per Leybold Ag. Product and Vacuum Technology Reference Book, 1990, Vacuum Technology section; Page 78. (Reference 10.8).
- **Roots Type Blower**: Sometimes referred to as lobe blowers or mechanical boosters. This device consists of a housing with 2 counter rotating figure 8 shaped rotors. The rotors are synchronized by a timing gear in such a way that there is no contact between the rotors or between the rotors and the housing. These pumps

require no lubrication. Definition per Atlas Copco, Compressor Installation Manual, 1969 Edition, Page 1:3. (Reference 10.6) and Leybold's Product and Vacuum Technology Reference Book, 1990, Vacuum Technology section; Page 14 (Reference 10.8).

- **Liquid Ring:** These pumps are similar in principle to the rotary vane pump except that a liquid, such as water or oil, provides the primary seal. The vanes are fixed and mounted on a single eccentrically placed rotor. They are capable of operating down to -29.5 in. Hg. (10 torr) and offer significant advantages in being able to handle airborne contaminants and small solid particulates. Definition per Atlas Copco, Compressor Installation Manual, 1969 Edition, Page 1:3. (Reference 10.6)
- **Rotary Screw:** These pumps are positive displacement devices, which contain two rotating helical screws. One of the screws is driven and the other serves as the idler. Suction air is brought into the rotating screws and compressed to the discharge of the pump. Vacuum capabilities are limited to about 15 in. Hg..Definition per Gast Manufacturing Company, Vacuum and Pressure Systems Handbook, 1986 edition. (Reference 10.17**)**

Rotary Motion Pumps (Non-Positive Displacement):

- **Centrifugal Fans (Exhauster**): A type of fan where air flows perpendicular with the fan shaft (i.e., forward curve, backward curves, backward inclined, radial, airfoil or tubular design), with the motor installed inside or outside the air stream depending on the housing configuration. These fans provide a large flow of air at suction vacuum pressure levels. They are capable of providing pressures down to 6 in. Hg. vacuum. Definition per Hoffman Air and Filtration Systems, 1986 edition, Centrifugal Compressor Engineering. Page 2 (Reference 10.9).
- **Axial Flow Fans:** A type of fan where airflows in-line with the fan shaft (i.e., vane axial, tube axial, propeller or axial roof ventilator), with the motor normally installed in the air stream. Definition per Hoffman Air and Filtration Systems, (Reference 10.25).

4.0 RESPONSIBILITIES

4.1 FWO-Systems, Engineering and Maintenance (SEM)

4.1.1 FWO-SEM is responsible for the technical content of this Criterion and monitoring the applicability and the implementation status of this Criteria and either assisting the organizations that are not applying or meeting the implementation expectations contained herein or elevating their concerns to the director(s).

Basis: LIR 301-00-01.11; Issuing and Managing Laboratory Operations Implementation Requirements and Guidance, Section 5.4, OIC Implementation Requirements.

4.1.2 FWO-SEM shall provide technical assistance to support implementation of this Criterion.

4.2 Facility Manager

4.2.1 Responsible for operations and maintenance of institutional, or Real Property and Installed Equipment (RP&IE) under their jurisdiction, in accordance with the requirements of this document.

4.2.2 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that may be assigned to the FM in accordance with the FMU-specific Facility/Tenant Agreement.

4.3 Group Leader

4.3.1 Responsible for operations and maintenance of those Personal Property and Programmatic Equipment (PP&PE) systems and equipment addressed by this document that are under their jurisdiction

4.3.2 Responsible for system performance analysis and subsequent replacement or refurbishment of assigned PP&PE.

4.4 Authority Having Jurisdiction (AHJ) - POC for Mechanical Chapter of LANL Engineering Manual

4.4.1 The AHJ is responsible for providing a decision on a specific technical question regarding this criterion.

5.0 PRECAUTIONS AND LIMITATIONS

5.1 Precautions

This section is not intended to identify all applicable precautions necessary for implementation of this Criterion. A compilation of all applicable precautions shall be contained in the implementing procedure(s) or work control authorization documents. The following precautions are intended only to assist the author of a procedure or work control document in the identification of hazards/precautions that may not be immediately obvious.

5.1.1 When planning for the disassembly of vacuum pumps it should be anticipated that oils may have migrated through the system, both up and down stream, and collected in the low points. When the vacuum system has been radioactively contaminated, plans should be made to handle contaminated organics and components that may be encountered.

Basis: Lessons Learned: Yellow Alert: Vacuum System D&D; ID L00-059 (Reference 10.15).

5.1.2 Vacuum pumps should not be stored near work areas unless measures are taken to ensure the fluid is secondarily contained. Before any work is started in the area of vacuum pumps, a survey should be made to check for oil spills and minimize the risks for employees slipping and falling.

Basis: Occurrence Report: ID: OAK-LLNL-LLNL-1995-0058; Employee Injury Which Required Inpatient Hospitalization (Reference 10.18).

5.1.3 When adjusting the belt tension on belt-driven vacuum pumps, it is important to perform a start-up procedure on the system. It is possible that belt adjustment can cause interference between static and rotating parts of the system. This interference can cause serious consequences, such as a fire in a critical component of a vacuum system.

Basis: Occurrence Report: RL—WHC-PFP-1995-0056; The 17 Vacuum Pump #2 Caught Fire-Building 236-Z (Reference 10.21).

5.1.4 In the performance of maintenance on vacuum system equipment and especially vacuum pumps, it is important to follow tracking procedures for the purpose of monitoring the radioactivity status of the equipment. Tracking procedures include documentation for the location and exposure contamination levels of vacuum pumps. Serious contamination problems can be the result of poor procedures.

Basis: Occurrence Report: ALO-LA-LANL-ACCCOMPLEX-1996-0009; Violation of Procedure Resulting in Loss of Control of Internally Radioactively Contaminated Vacuum Pump (Reference 10.22).

Lessons Learned: ID No. L-1998-OEWS-04-01; Repair of Internally Contaminated Vacuum Pump Spreads Contamination Pump (Reference 10.7).

5.2 Limitations

The intent of this Criterion is to identify the minimum generic requirements and recommendations for SSC operation and maintenance across the Laboratory. Each user is responsible for the identification and implementation of additional facility specific requirements and recommendations based on their authorization basis and

unique equipment and conditions, (e.g., equipment history, manufacturer warranties, operating environment, vendor O&M requirements and guidance, etc.).

Nuclear facilities and moderate to high hazard non-nuclear facilities will typically have additional facility-specific requirements beyond those presented in this Criterion. Nuclear facilities shall implement the requirements of DOE Order 4330.4B (Ref. 10.3) (or 10 CFR 830.340, Maintenance Management, when issued) as the minimum programmatic requirements for a maintenance program. Additional requirements and recommendations for SSC operation and maintenance may be necessary to fully comply with the current DOE Order or CFR identified above.

Mechanical pumps that are installed in glove boxes in nuclear facilities are not repaired. The usual practice is to replace the pump assembly at the end of its life or when mechanical problems develop.

6.0 REQUIREMENTS

Minimum requirements that Criterion users shall follow are specified in this section. Requested variances to these requirements shall be prepared and submitted to FWO-SEM in accordance with LIR 301-00-02 (Ref. 10.1), "Variances and Exceptions to Laboratory Operations Requirements," for review and approval. The Criterion users are responsible for analysis of operational performance and SSC replacement or refurbishment based on this analysis. Laws, codes, contractual requirements, engineering judgement, safety matters, and operations and maintenance experience drive the requirements contained in this section.

6.1 Operations Requirements

6.1.1 The operation of vacuum pumps can be complicated and dangerous to operating personnel. The manufacturer's procedures must be followed for systems containing roots blowers, centrifugal blowers, rotary screw vacuum pumps and large liquid ring pumps.

Basis: Based upon Occupational Safety and Health Administration regulation (Reference 10.29). Compliance with this standard is required per Appendix G of the UC Contract.

6.2 Maintenance Requirements

6.2.1 No maintenance requirements for vacuum pumps have been identified.

7.0 RECOMMENDATIONS AND GOOD PRACTICES

The information provided in this section is recommended based on acceptable industry practices and should be implemented by each user based on his / her unique application and operating history of the subject systems / equipment.

7.1 Operations Recommendations

7.1.1 When using most mechanical vacuum pumps in a system containing water vapor, it is recommended that the gas ballast valve be open. This will increase the water handling capacity of the system. After pumping moisture, the pump should be run with the gas ballast open and the inlet blanked off for a period of one (1) hour minimum, or until the oil is clear, to remove all moisture from the pump to prevent rusting when the pump is shut down.

Basis: This procedure is recommended by the pump manufacturers. Operating Instruction for DK and WA Pumping Systems by Leybold-Heraeus Vacuum Products, Inc. (Reference 10.11).

7.2 Maintenance Recommendations

7.2.1 Routine recommended maintenance is presented in the **Appendix B Matrix**. Because of the wide variety of vacuum pump types and manufacturers used at LANL, this Matrix simplifies the maintenance recommendations for the majority of users.

Basis: Occurrence Report: ID No.: OAK-LLNL-LLNL-1995-0058; Employee Injury Which Required Inpatient Hospitalization. (Ref. 10.19)

Occurrence Report: OH-WV-WVNS-VFS-1998-0002; Air Monitor Sample Pumps Fail in the Vitrification Facility. (Ref. 10.20)

7.2.2 In the procedure for changing fluids in mechanical pumps during preventative maintenance programs, checklists of task details should be a routine part of the programs.

Basis: Occurrence Report: ALO-LA-LANL-TA55-1996-0013; Continuous Air Monitor Alarm. (Reference 10.23)

7.2.3 For vacuum pumps that have coolant systems, remove and calibrate the temperature switches on an annual basis.

Basis: Occurrence Report: RL-WHC-ANALLAB-1996-0025; “The #3 Facility Vacuum Pump Unexpectedly Tripped Off Line.” (Reference 10.20)

8.0 GUIDANCE

8.1 Operations Guidance

No implementing guidance available.

8.2 Maintenance Guidance

The documents listed in this section contain past and current procedures for performing maintenance on equipment included in this Criterion.

8.2.1 Provided it has been reviewed and approved by FWO-SEM, an acceptable program for vacuum system maintenance may be found in JCNNM, PMI Number 40-25-006: "Vacuum Pump Equipment Maintenance and Repair" (Reference 10.3), and ESH-17-132 (RRES-MAQ-132 REV. 3): "Exhaust Stack Air Monitoring System Maintenance, Repair, and Installation" (Reference 10.4).

9.0 REQUIRED DOCUMENTATION

Maintenance history shall be maintained for Vacuum pumps to include, as a minimum, the parameters listed in Table 9-1 below:

Table 9.1 Documentation Parameters

MAINTENANCE HISTORY DOCUMENTATION PARAMETERS				
PARAMETER	**ML 1**	**ML 2**	**ML 3**	**ML 4**
Maintenance Activities				
Repair / Adjustments	**X**	**X**		
Check Alarm Systems	**X**	**X**		
PM Activities	**X**	**X**	**X**	
Equipment Problems				
Failure Dates	**X**	**X**		
Failure Root Cause	**X**	**X**		
Inspection Results				
Inspection Date	**X**	**X**		
Inspection Logs	**X**	**X**		

Basis: Documentation of the parameters listed in Table 9-1 above satisfies the requirements of LPR 230-07-00.0, Criteria 2, (Reference 10.30) which states; "Maintenance activities, equipment problems, and inspection and test results are documented."

10.0 REFERENCES

The following references, and associated revisions, were used in the development of this document. Facility specific O&M procedures written to the requirements of this criterion should use the latest, LANL approved, revision of these documents.

10.1 LIR301-00-02.3: Exceptions or Variances to Laboratory Operations Requirements. April 2000.

10.2 DOE Order 4330.4B, Section 3.4.9: Maintenance Management Program, February 10, 1994.

10.3 JCNNM, PMI Number 40-25-006: Vacuum Pump Equipment Maintenance and Repair.

10.4 ESH-17-132 (RRES-MAQ-132 REV. 3): Exhaust Stack Air Monitoring System Maintenance, Repair, and Installation.

10.5 Varian Associates, 1984 Edition: Basic Vacuum Maintenance Training Workbook.

10.6 Atlas Copco, Compressor Installation Manual, 1969 Edition, Page 1:3.

Atlas Copco, Stationary Air Compressors, Instruction Book, Page 16.

10.7 Lessons Learned: ID No. L-1998-OEWS-04-01; Repair of Internally Contaminated Vacuum Pump Spreads Contamination.

10.8 Leybold Ag., Product and Vacuum Technology Reference Book, 1990, Vacuum Technology Section 18; Pages,4, 14, and 78.

10.9 Hoffman Air and Filtration Systems, 1986 edition, Centrifugal Compressor Engineering. Page 2

10.10 Leybold Ag., Operation and Maintenance Manual for Roots Pumps, Bulletin 1-87.

10.11 Leybold Ag., Operating Instruction for DK and WA Pumping Systems, Vacuum Products, Inc.

10.12 Edwards High Vacuum, Vacuum Technology, 1981, Nigel S. Harris.

10.13 Travaini Pumps USA, Rotary Vane Vacuum Pump Systems Installation and Operations Manual. (Edition not available)

10.14 Travaini Pumps USA, Operating & Maintenance Manual for Liquid Ring Vacuum Pumps, Compressors & Systems, August, 2000.

10.15 Lessons Learned: Yellow Alert:Vacuum System D&D; ID L00-059.

10.16 LIR402-1200-01-0, Pressure, Vacuum, and Cryogenic Systems.

10.17 Gast Manufacturing Company, Vacuum and Pressure Systems Handbook, 1986 edition.

10.18 Occurrence Report: ID No.: OAK-LLNL-LLNL-1995-0058; Employee Injury Which Required Inpatient Hospitalization.

10.19 Occurrence Report: OH-WV-WVNS-VFS-1998-0002; Air Monitor Sample Pumps Fail in the Vitrification Facility.

10.20 Occurrence Report: RL-WHC-ANALLAB-1996-0025; The #3 Facility Vacuum Pump Unexpectedly Tripped Off Line; CAM installation at Hanford.

10.21 Occurrence Report: RL-WHC-PFP-1995-0056; The 17" Vacuum Pump #2 Caught Fire - Building 236-Z.

10.22 Occurrence Report: ALO-LA-LANL-ACCCOMPLEX-1996-0009; Violation of Procedure Resulting in Loss of Control of Internally Radioactively Contaminated Vacuum Pump.

10.23 Occurrence Report: ALO-LA-LANL-TA55-1996-0013; Continuous Air Monitor Alarm.

10.24 DOE Order 430.1A. Life Cycle Asset Management Order. Attachment 2: Contractors Requirements Document, Page 14, 10-14-1998.

10.25 Hoffman Air and Filtration Systems, Hoffman Centrifugal Blowers and Exhausters, Instruction Manual No. AM-412D, Nov. 1990.

10.26 Sullair Corporation, Sullair Vacuum System, Operator's Manual and Parts List, 1990, Section 6, Maintenance.

10.27 Facility Piping Systems Handbook, page 15.6, 1996, by Michael Frankel.

10.28 Becker Technical Document, Future Technology in Medical Vacuum Pumps, Oct. 2000, pages 4 and 5.

10.29 OSHA 1910.212, Occupational Safety & Health Administration "General Requirements for all Machines," subpart title "Machinery and Machine Guarding."

10.30 LPR 230-07-00, Maintenance History, Criteria 2, Feb. 1997.

11.0 APPENDICES

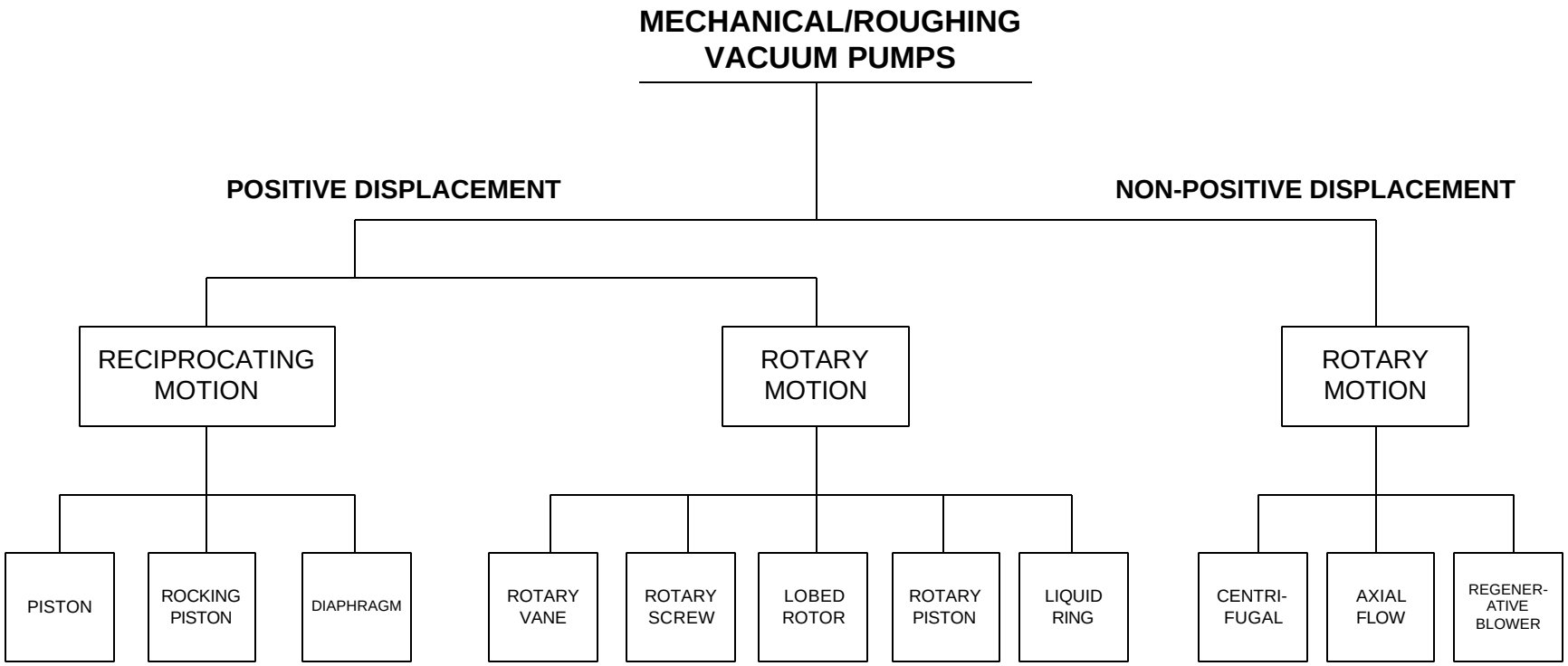
Appendix A: Types of Vacuum Pumps

Appendix B: Vacuum Pumps-Matrix of Recommended Maintenance

Appendix C: Known Manufacturers Used at LANL

APPENDIX A

LANL O & M MANUAL
CRITERION 418 - VACUUM PUMPS



APPENDIX B

Criterion 418 - Vacuum Pumps
Matrix for Recommended Maintenance Tasks

MAINTENANCE INTERVALS: **Weekly = W** **Monthly = M** **Semi-Annual = SA** **Annual = A** **Not Applicable= NA**

	PUMP TYPE								
						CENTRIFUGAL & AXIAL	ROOTS BLOWERS		
MAINTENANCE TASK	**ROTARY VANE, WET**	**ROTARY VANE, DRY**	**RECIPROCATING**	**ROTARY PISTON**	**LIQUID RING**	**VACUUM BLOWERS**	**(LOBE BLOWERS)**	**ROTARY SCREW**	**DIAPHRAGM**
OIL/FLUID CHANGE	SA	NA	SA	SA or @ 1000 hrs	@500 hrs	NA	@3000 hrs	SA	NA
CLEAN FLUID LINE STRAINERS	NA	NA	NA	NA	M	SA	SA	@4000 hrs	NA
INSPECT BELTS/COUPLING ALIGNMENT	SA	SA	SA or 10,000 hrs	SA	SA	SA	SA	SA	NA
CHECK PUMP OIL LEVEL	M	NA	M	M	W	M	NA	W	NA
CHECK BEARING LUBRICATORS		NA	NA	NA	@2,000 hrs	M	SA	SA	NA
CHECK GEAR HSG OIL LEVEL	NA	NA	NA	SA or @ 1000 hrs	NA	M	SA	NA	NA
CHECK SUMP FLUID LEVEL	NA	NA	W	W	@200 hrs	NA	NA	W	NA

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	PUMP TYPE								
						CENTRIFUGAL & AXIAL	ROOTS BLOWERS		
MAINTENANCE TASK	ROTARY VANE, WET	ROTARY VANE, DRY	RECIPROCATING	ROTARY PISTON	LIQUID RING	VACUUM BLOWERS	(LOBE BLOWERS)	ROTARY SCREW	DIAPHRAGM
CLEAN/REPLACE AIR FILTER	A	A	A	NA	W	@2,000 hrs	NA	NA	NA
CHANGE OIL FILTER/ELEMENT	SA	NA	SA	SA	SA	NA	SA	@4000 hrs	NA
REPL. AIR SEPARATOR ELEMENT	NA	NA	NA	NA	SA	NA	NA	A	NA
CHECK BELT TENSION/CONDITION	SA	SA	2500 hrs.	A	A	SA	SA	SA	NA
VIBRATION TESTING	A	A	A	A	A	A	A	A	A
LUBE PUMP BEARINGS	SA	@5000 hrs	SA	SA	@2000 hrs	NA	SA	SA	NA
LUBE MOTOR BEARINGS	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510
CHECK FOR BEARING NOISE	A	M	A	A	SA	M	A	SA	A
CHECK SUCTION PRESSURE	A	A	M	M	M	M	M	M	M
CHECK SYSTEM LEAKS	SA	SA	SA	SA	W	SA	M	M	M

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					PUMP TYPE				
						CENTRIFUGAL & AXIAL	**ROOTS BLOWERS**		
MAINTENANCE TASK	**ROTARY VANE, WET**	**ROTARY VANE, DRY**	**RECIPROCATING**	**ROTARY PISTON**	**LIQUID RING**	**VACUUM BLOWERS**	**(LOBE BLOWERS)**	**ROTARY SCREW**	**DIAPHRAGM**
CHECK BEARING TEMPERATURES	SA	SA	SA	SA	M	M	SA	SA	SA
CHECK MECHANICAL SEALS	NA	NA	NA	NA	@4000 hrs. SA	NA	NA	NA	NA
CHECK LUBE OIL CONTAMINANTS	M	NA	SA	SA	M	NA	NA	M	NA
CHECK SEAL/COOLANT LEVEL	NA	NA	NA	M	W	NA	NA	M	NA
CHECK MOUNTING STRUCTURE	A	A	A	A	A	A	A	A	A
VERIFY MOTOR CURRENT DRAW	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510	Refer to O&M 510
CHECK ELECTRICAL BREAKERS	SA	SA	SA	SA	SA	SA	SA	SA	SA
CHECK FUSES	A	A	A	A	A	SA	SA	SA	A
INSPECT TERMINALS	A	A	A	A	A	A	A	SA	A

APPENDIX B

	PUMP TYPE								
						CENTRIFUGAL & AXIAL	ROOTS BLOWERS		
MAINTENANCE TASK	**ROTARY VANE, WET**	**ROTARY VANE, DRY**	**RECIPROCATING**	**ROTARY PISTON**	**LIQUID RING**	**VACUUM BLOWERS**	**(LOBE BLOWERS)**	**ROTARY SCREW**	**DIAPHRAGM**
CHECK ALARMS	SA	SA	SA	SA	SA	SA	SA	SA	SA
Reference No. See Pg. 9,10 for details.	10.12, 10.19	10.13, 10.17, 10.27, 10.19	10.6	10.11	10.13, 10.14	10.25	10.8, Sec18, pg.78	20.26	10.17

APPENDIX C

Known Manufacturers Used at LANL									
						CENTRIFUGAL & AXIAL	ROOTS BLOWER		
	ROTARY VANE, WET	ROTARY VANE, DRY	RECIPROCATING	ROTARY PISTON	LIQUID RING	VACUUM BLOWERS	(LOBE BLOWERS)	ROTARY SCREW	DIAPHRAGM
	LEYBOLD	LEYBOLD	STOKES	LEYBOLD	TRAVAINI	HOFFMAN	LEYBOLD	QUINCY	GAST
	KINNEY	SUTORBILT/GARDNER DENVER	QUINCY	GAST	BEACH RUSS	GAST	SUTORBILT/GARDNER DENVER	INGERSOL RAND	BOSCH
	EDWARDS	EDWARDS	BEACH-RUSS		EDWARDS		ROOTS CONNERSVL.	SULLAIR	
	TRAVAINI	TRAVAINI	KINNEY		NASH		EDWARDS		
	GAST	GAST	EDWARDS		SULLAIR				
	NASH	BUSCH	GAST						
	WELCH	POWEREX	GARDNER DENVER						
	BECKER	BECKER							